Aerosol Concentrations and Fluxes near the Ocean Surface during the Rough Evaporation Duct (RED) Project

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LONG-TERM GOALS

The overall aim of this project is to improve substantially the parameterisation of sea spray particulate fluxes for a wide range of environmental conditions. To meet US Navy needs for more accurate predictions of aerosol loadings, the underlying physical and chemical processes determining aerosol formation and evolution in the maritime environment must be defined. Progress is already being made with the formulation of aerosol models, such as NAAPS, which aim to provide a mesoscale aerosol predictive capability. However, to date, these models have concentrated upon the smaller accumulation mode aerosol components ($r < 1\mu m$) of importance in defining general air mass turbidity and radiative impacts. Close to the sea surface and in localised regions, these models must be extended to incorporate predominantly wind-driven sea spray generation and surf zone aerosol processes to deal with current and future Navy requirements (De Leeuw *et al*, 2000, Reid *et al*, 2001). In addition to its primary purpose of addressing the sea spray source function, this work aims to provide detailed atmospheric particulate measurements in order to permit closure between electro-optical propagation and aerosol properties in the RED project, undertaken in Hawaii during August/September 2001.

OBJECTIVES

The development of lightweight, robust and relatively inexpensive optical particle counters based upon modified Met One aerosol sensors has proceeded satisfactorily with two prototypes being deployed during an associated project, for testing purposes. On the basis of these trials, design improvements have been made and a number of units are currently under construction to be employed for sea spray flux studies and other investigations in FY02/03. In addition, results from the earlier measurement campaign undertaken during the RED project are presented. These observations are focused on the smaller particles measured at the Malaekahana beach site during RED. Analysis of sea spray fluxes measured on R/P FLIP is on-going and will be reported subsequently.

APPROACH

Met One (a division of Pacific Scientific) manufactures a range of compact particle counting instruments based around a very small scatter cell measuring approximately 7 x 3 x 3cm, including the circuit board containing the laser diode power supply and signal preamplifiers. Despite its small size,

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14. ABSTRACT

The overall aim of this project is to improve substantially the parameterisation of sea spray particulate fluxes for a wide range of environmental conditions. To meet US Navy needs for more accurate predictions of aerosol loadings, the underlying physical and chemical processes determining aerosol formation and evolution in the maritime environment must be defined. Progress is already being made with the formulation of aerosol models, such as NAAPS, which aim to provide a mesoscale aerosol predictive capability. However, to date, these models have concentrated upon the smaller accumulation mode aerosol components (r < 1??m) of importance in defining general air mass turbidity and radiative impacts. Close to the sea surface and in localised regions, these models must be extended to incorporate predominantly wind-driven sea spray generation and surf zone aerosol processes to deal with current and future Navy requirements (De Leeuw et al, 2000, Reid et al, 2001). In addition to its primary purpose of addressing the sea spray source function, this work aims to provide detailed atmospheric particulate measurements in order to permit closure between electro-optical propagation and aerosol properties in the RED project, undertaken in Hawaii during August/September 2001.

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this unit operates with a sample flow rate of about 50ml/s, which is substantially greater than many, much larger particle spectrometers. The Leeds group has been working with this unit to develop a compact, robust, lightweight and relatively inexpensive instrument for use in a number of applications where these properties are especially beneficial. In addition to Professor Michael H Smith, who leads the group, the team comprises Mr Martin K Hill and Dr Barbara J Brooks. Following work on the laboratory-based prototype reported last year, two units were constructed, each with a microprocessor-controlled 8-channel analyser.

The measurements undertaken at Malaekahana included black carbon loadings, by means of a Magee Scientific aethalometer, aerosol particle radii from 7nm to 0.150µm, TSI Scanning Mobility Particle Sizes, and total particles with radii greater than 3nm, TSI 3025 Condensation Particle Counter. Aerosol particle size and composition was determined by a Particle Measuring Systems ASASP-X optical particle counter in combination with a custom-designed heater to determine particle volatility.

WORK COMPLETED

An atmospheric chemistry research project on the west coast of Ireland organised by colleagues at Leeds during July/August 2002 provided a good opportunity to evaluate the compact optical particle counters for an extended period of nearly 7 weeks in the field. One unit, designed to provide 8-channel spectra at 10Hz, was linked to a laptop computer for data collection and storage. It was operated alongside optical particle counters for comparison purposes and with its intake close to the sample volume of an ultrasonic anemometer to demonstrate its use in determining particle fluxes by eddy covariance methods. The other unit was built into a sonde package and included temperature, relative humidity, atmospheric pressure and wind speed measurements, with particulate and meteorological data being recorded in flash memory. This unit, shown in Fig. 1, was operated beneath a helium balloon (approx $10m^3$) to obtain atmospheric profiles from the surface to approximately 150m.

Fig. 1:The prototype optical particle counter sonde operated on a helium balloon and opened to show its components –-scatter cell, small pump and data acquisition system.

Work on the Malaekahana data has also been completed. It indicates that there was little change in the accumulation mode particle properties throughout the experiment apart from during periods of local pollution either at the site, or when local winds brought anthropogenic particles from towns along the coast of Oahu.

RESULTS

At times when the sonde could not be operated on the balloon due to high winds, a simple pulley system on the 20m mast at Mace Head was used to profile the lowest region of the atmosphere. Measurements from one period of on-shore airflow are illustrated in Fig. 2 to demonstrate the operation of the sonde.

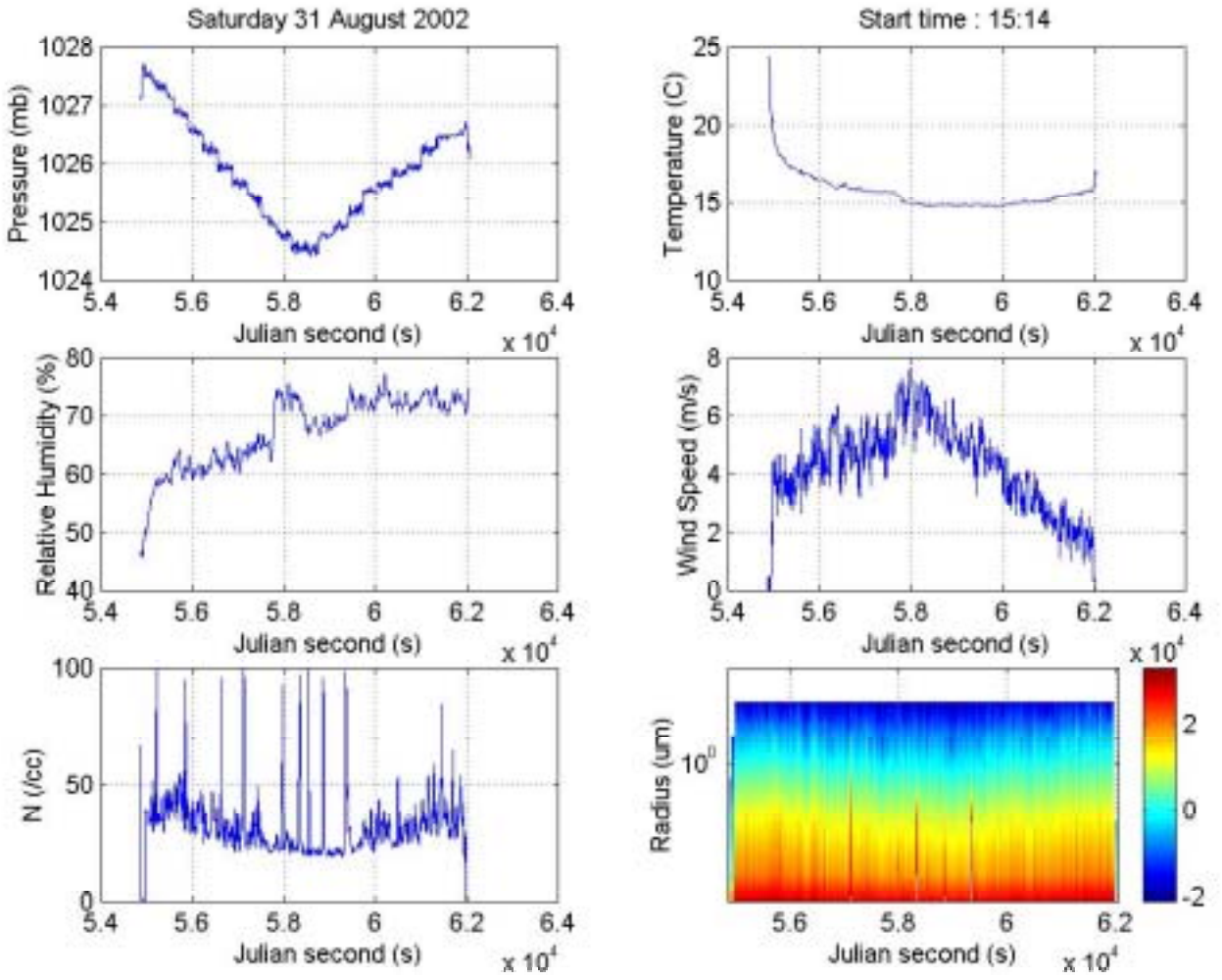

Fig. 2: Observations aerosol particle spectra and concentrations from the sonde, together with pressure, temperature, relative humidity and wind speed around low tide. (NB Discontinuities at the start and end of the run arise when the probe is inside the laboratory for initialisation and data download, respectively).

The profile lasted around 2 hours with the sonde spending a few minutes at each level in approximately 2m steps. Over the whole period, relative humidity increased from about 60 to 70%, with a decline in wind speed from 4 to 2m/s, although the wind speed increased with altitude to a maximum of 6m/s. Mean particle concentrations were similar near the surface but showed a marked decline with altitude, although there were sharp bursts of increased particle concentrations at all levels. This finding was somewhat surprising and suggests the presence of a plume structure, as observed near the surf zone in several earlier EOPACE experiments (Jensen et al, 2002). The contribution of these particle bursts was more significant against the lower particle concentrations found at higher levels and demonstrated that the plumes were sufficiently vigorous to transport particles to levels of about 20m above the surface (approximately 30m amsl).

The main features of the Malaekahana observations are shown in Figs 3 and 4. A record of the elemental carbon loadings throughout the experiment is presented in Fig. 3 and demonstrates that the air was generally clean with carbon levels below 40ng m^{-3}, although excursions to substantially higher levels were recorded during the pollution episodes mentioned previously.

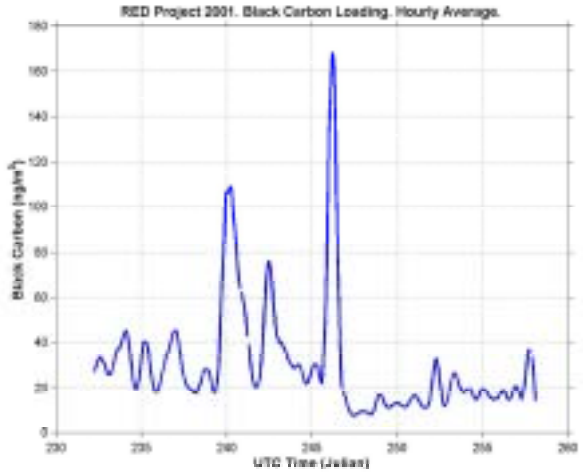

Fig. 3: elemental carbon loadings for the whole of project

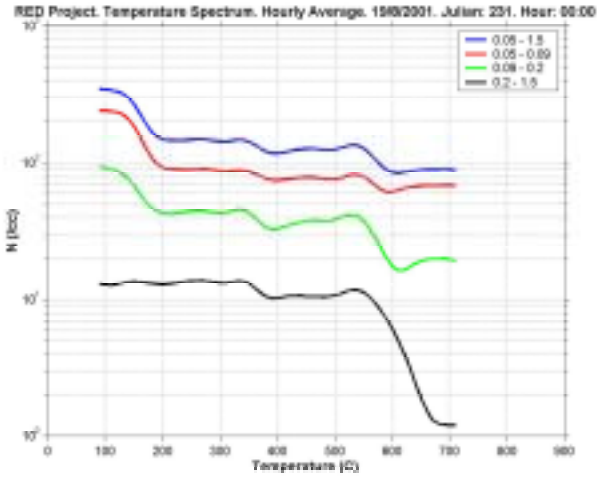

Fig. 4: Typical volatility results within RED 4 size bands for the RED project.

There was little change in the composition of the sub-micron aerosol particles throughout the RED project (apart from during the local pollution episodes). A typical set of volatility results (O'Dowd *et al*, 1992, O'Dowd & Smith, 1993, Smith & O'Dowd, 1996, Brooks *et al*, 2002) is shown in Fig. 4 from which it may be noted that sea salt particles (volatile around 600°C) are present in all size bands. Although there was generally some limited whitecap activity (and hence sea salt production) over the open ocean, the majority of these particles were probably produced in the surf zone close to the instrumentation at the beach site. Ammonium sulphate/bisulphate particles (volatile around 150°C) dominate the 3 smaller size ranges, and comprise the majority of particles measured by this instrument (note that the graph scales are logarithmic). It is difficult to establish the presence of specific organic compounds within the aerosol particles by the volatility technique as such materials usually dissociate gradually at increasing temperatures. However, the lack of any sloping change in particle concentration with temperature suggests that there was little, if any, organic material within the aerosol. Residual non-volatile particles present at temperatures of 700°C are generally either soot or dust particles. The fact that the proportion of such particles rises from perhaps 10% to around 30% for decreasing particle size bands points to the smaller ones being soot carbon, and the larger ones dust, since soot particles are generally around 0.1μm or smaller in radius.

Measurements made with the SMPS and total particle counters during this project (not shown) indicated that particle concentrations were dominated by accumulation mode particles with radii around 0.1μm or so.

IMPACT/APPLICATION

The instruments under development have the benefit of very small size and relatively low cost, promoting their application on a variety of platforms and in situations where physical risks to the instruments precludes the use of more expensive commercial optical particle counters.

TRANSITIONS

Plans are in progress to utilise a number of such instruments close to the ocean surface to measure sea spray production by eddy covariance and profile methods. Other experiments are being planned to examine the indirect aerosol effect, where changes in aerosol concentrations and properties lead to increased droplet nucleation in clouds with consequent changes in cloud albedo and hence in the radiative properties of the atmosphere. By mounting a series of these instruments beneath a tethered balloon, aerosol and cloud droplet concentrations immediately below, at and above cloud base, respectively, will be measured simultaneously. Also, interest in incorporating these devices into a number of other projects has been expressed by other scientists in the UK and Europe.

RELATED PROJECTS

The North Atlantic Marine Boundary Layer Experiment (NAMBLEX) to study the oxidising capacity of the marine atmosphere was led by colleagues at Leeds and other UK universities. It provided an excellent framework within which the performance of the Met One optical particle counter prototypes could be fully evaluated alongside very many other aerosol particle samplers and instruments.

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